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MODELLING OF THE INTERACTION BETWEEN SUPPLY AND DEMAND FOR MEDICAL STAFF ON THE BASIS OF FUZZY SITUATIONAL ANALYSIS

In this article, the specificity of the medicine staff labour market is shown, factors of supply and demand evaluation are analyzed. Multivariate levels of supply and demand interaction modelling on the medical staff labour market, the goals and statement of supply and demand management problem are reviewed. Model of management of supply and demand for medical staff on micro level, based on fuzzy situational analysis and fuzzy pattern recognition.

Keywords: *labour market of medicine staff, demand and supply, demand model, the model of offers, situational management, fuzzy etalon and real situations, fuzzy recognition of situations.*

Introduction

The results of health system activity and quality of medical service rendered to the population completely depend on quality and quantity of health specialists (HS). Therefore, the improvement of medical staff stock and raise of health specialists professional level are important challenges the special attention of each country and generally of World Health Organization (WHO) is given to [1–3]. Currently great significance is attached to highly qualified staff training, additional training for perfection of professional qualities, knowledge and skills of health specialists, staffing and improvement of health quality indicators.

Despite of all abovementioned, the tendency of staff shortage, personnel decrease is now observed [4–7]. It is announced that number of staff shortage in USA for 2020 is prognosticated to be 85000 people, and for 2025 the demand and supply will gain the upper hand from 46000 to 90000 [7]. The number of doctors per 10000 people for 2011–2014 has decreased in Ukraine from 49 to 48, in Belorussia – from 54 to 39, in Azerbaijan – from 37 to 35 [8]. In Turkey the number of people per a doctor is 595, whereas this indicator equals 262 in Germany, 203 in Ukraine, 290 in Azerbaijan [9].

The number of doctors per 100000 people was 501 in 2009, whereas in 2011, this figure decreased to 418. In 2012, the number of doctors decreased by 7261, resulting in the demand for 150 000 doctors [6–10]. It is reported that the number of doctors per 10000 people in Russia in 2013 and 2014 was 49 [8].

Under the total number of doctors it is provided to take into account all highly-educated doctors who work in treatment, sanitary, social security institutions, scientific and research institutes, postgraduate education training and other health bodies [8].

Health specialists also include nursing staff (paramedic, obstetrician, nurse). Most of the world countries claim the shortage of nursing staff. Despite the doctor/nurse ratio number in Finland equals 1:4,3, in Norway –1:4,7, and in Denmark –1:5,6, these countries still announce the fact of nursing staff shortage [5-6], as in Britain nurse shortage number was presented up to 35000, and in Finland up to 100000. One of the factors generating this problem is application of information and communication technologies, as well as modern innovative medical technologies in medical sphere, formation of e-health, and it reasons the partial decrease of demand for doctors and increase of demand for nursing staff [11- 13].

Thus, present picture in the sphere of doctor and nursing staff displays the excess of demand over the supply in health specialist labor market, and it makes the issues of regulation and management of demand and supply for health specialists essential at governmental and WHO level [1–4]. Successful solution of this problem requires complex approach to the problem, and development of comprehensive strategy encompassing staff compensation, working conditions, their recruitment and retention issues. Still, there is not any standard model in this direction as well as any country to borrow its “best practice” in order to find appropriate problem solution to the

stated issue [3]. According to the results abovementioned issues in health specialist policy have been partially embraced in such countries leading in the medical sphere as England, Belgium, Germany, Ireland, Spain, Lithuania, Slovenia, Finland, Australia and Canada. In these countries necessary source for monitoring of health specialist labor market is availability of an information base maintaining reliable, precise and new data.

In order to find the answers to all abovementioned questions and in the development of correct staffing policy, the priority is given to sociological survey method, initiating by WHO from 1990. Topicality of this approach reasoned by the lack of scientific methodology in this field, and shortage of scientific works devoted to this issue [3]. The study case proposed a scientific and methodological approach to the management of supply and demand in the market of medical staff, and develops a method based on fuzzy situations analysis and fuzzy images recognition for the management of supply and demand in micro-level, i.e., human resource recruitment.

Specific features of the health specialists labor market

According to WHO's initiative the medical staff has to be assessed by their competency and position every 5, 10, 15 years in each country [3]. This is chiefly demanded by the following 4 arguments: 1) the demand for health care services varies depending on the changes of the demographic, epidemiological, cultural and social characteristics of the population; 2) the users' expectations change, migration occurs, technical innovations (diagnostic and treatment equipment and methods; telemedicine) develop and organizational changes aimed at improving the quality of health of the system (the first medical and sanitary aid, working on brigade method, services integration, new contract terms and working conditions) arise; 3) feminization of some professions (e.g. dentistry) takes place, and opinions of the current workers to the quality of life differ from the previous generation of workers and these changes affect the activity of the labor market and labor productivity; 4) the changes taken place within the period of time between the decision making and its implementation in accordance with these changes should be taken into account. The training of new personnel requires opening of new educational institutions, while attracting additional human resources with new quality requires the analysis of existing curriculum and development of new ones. All this takes years.

At present, as an important part of the assessment of the demand for medical personnel, the following shall apply:

- identification of the demand for personnel in regions;
- estimated number of population;
- technological and social changes;
- vocational qualification structure;
- quality of professional performance on individual-level;
- healthcare policy [3, 4].

Thus, here are the following challenges to define demand and supply for health specialists:

- What will be future short-, medium- and long-term perspectives for demographic, epidemiological, social and cultural characteristic features of the population;
- Increase of which chronic illnesses, psychological states is prognosticated, and emerging probability of new future diseases in the result of migration flow and climate changes;
- What are the requirements for appropriate future medical service;
- What will citizens' and users' requirements be, who will be financing appropriate medical services;
- How will the technological and organizational change affect the demand;
- What kind of specialists and their amount (general practitioner, specialist physicians, paramedics, nurses and others) will be required; what responsibilities and education of the health specialists together with their compensation rates will be in demand.

In terms of coverage of medical services rendered to the population, to ensure the adequacy of assessment the demand for the medical staff with the reality, the demand for the personnel depends on the expectations from the “adequate human resources” in terms of final outcome quality (Figure 1).

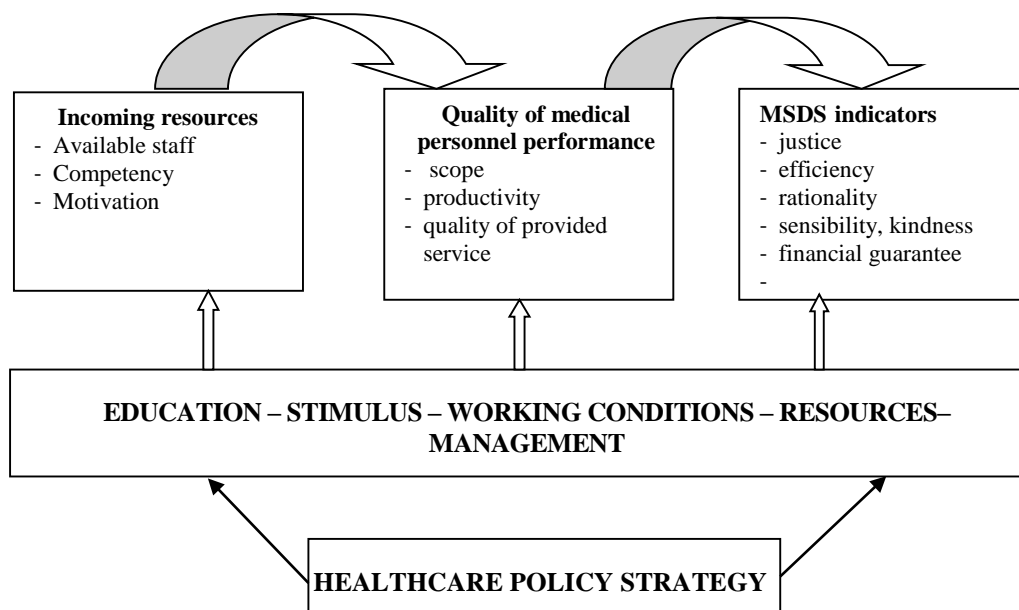


Figure 1. The quality of medical personnel and medical service delivery system (MSDS) performance [3]

Thus, the correct prediction of demand requires a proper evaluation of the current situation of the medical staff and the future staffs incoming and outgoing from this market (Figure 2).

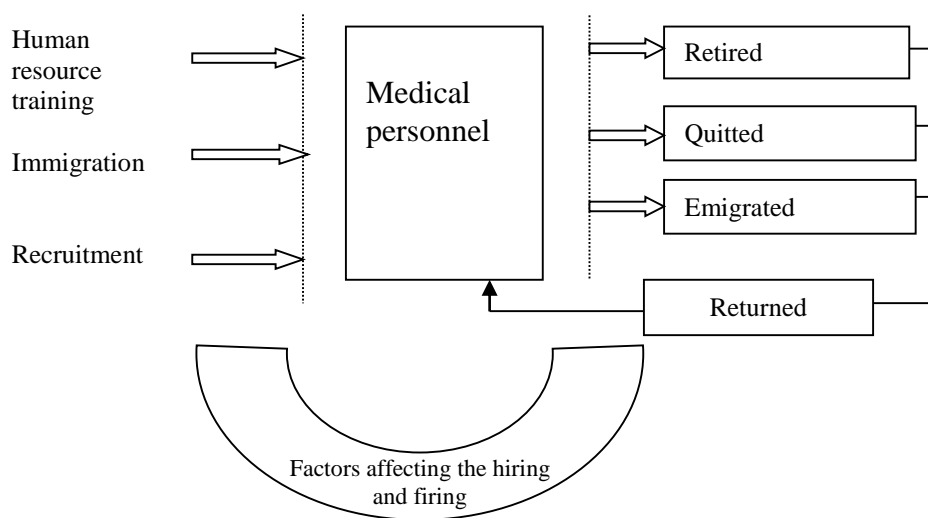


Figure 2. model of the existing human resources’ dynamics in healthcare [3]

The following approaches and methods are used for the assessment of demand for medical personnel:

- assessment based on the ratio of the total population to the number of medical staff;
- assessment based on the medical service indicators and the demand for these services;
- assessment based on the aimed service indicators;
- assessment based on needed medical services.

These approaches, according to the WHO's initiative, are referred to the survey methods and allow quantitative assessment of supply and demand of the medical staff.

Above-mentioned factors of supply and demand in the market of medical personnel characterize it as a socio-economic ("soft") system, because the main resource of the labor market is a human, his intellectual capacity, personal and psychological qualities, his value, without which the management of the social system will not be effective.

The specific features of the HS labor market, the uncertainty of information flows about its state, the much-varied profile of data on HS and the difficulties of measuring it, and the ambiguity of indicators characterizing it predetermine the variety of possible fuzzy states of supply and demand for HS and the multi-option pattern of reconciling them. Comparisons and evaluations of these conditions and the choice of the reconciliation policy can be efficiently accomplished with the use of intellectual methods and technologies. The latter help to integrate the versatile information on the supply and demand conditions and facilitate the development of a set of alternatives for managerial decisions and the selection of the most efficient one among them. Management in such systems is considered as a process of identification of the demand and supply condition at a given point in time and decision making suitable in the current situation.

Modeling the interaction between supply and demand in the HS labor market

The rise of an information economy emphasizing knowledge as its major value produces a significant influence on labor market deformations. The emphasis shifts toward human resources and the creative aspect of activities, which modifies the basic foundations of a "transaction" in the supply and demand relationship [14, 15].

In medical sphere these features shows itself more clearly, so the subjects here must demonstrate that they are intellectual potential carriers with certain personal, cultural, behavioral quality, and that they ready to adequately apply their competencies in particular workplace.

Given the realities of the modern labor market, the employer understands that the employee is a key strategic resource of the organization and tries to find and introduce new innovative approaches to the personnel policy (recruitment, job retention and motivation of staff). Nowadays, it is impossible to gain the maximum results from an employee with minimal expenses on his/her development. No expectation is warranted of a creative approach to job tasks or quality level of performance without considerations for the HS preferences (aspirations, interests, and motivations) facilitating his or her professional and often personal development [16].

The task of modeling and managing the interaction between demand and supply in the market for HS can be considered at micro and macro levels [17]. The micro level identification of the supply and demand conditions is viewed from the point of individual subjects in the HS labor market and their behaviors and strategies. At the macro demand level, the basic unit is an enterprise because it is at the enterprise level that the demand for HS is shaped in terms of structure and volume, as well as requirements regarding professional and personal competencies. In this case, the task of defining the level of conformity between supply and demand consists in the development of efficient selection and recruitment of HS.

At the macro level, the task of modeling and managing the interaction between demand and supply in the HS labor market, depending on the objectives, comes to balancing the supply and demand for HS within different territorial and geographic areas (at the industrial, regional, and nationwide levels, etc.) (Features of diseases in the regions, which specialty of doctors is demanded, distribution of the doctors, training of qualified personnel, the situation in the related field of education, the need for reforms in education, etc.).

Success in performing job functions depends on the HS intellectual potential, level of certain professional and personal competencies, willingness to properly employ them in the workplace, and desire and ability to expand and update professional knowledge and experience in line with functional requirements. Against this context, it seems worthwhile to address the labor market as an

intellectual environment [18-19], where the commodity is knowledge, abilities, and skills.

By intellectual smart management of the HS labor market, the authors mean managerial decision making to bring down the imbalance between the demand for HS and their supply, which comes to a choice between possible alternatives of the supply and demand reconciliation policy toward solutions that will satisfy as fully as possible the aims and conditions of the objectives set and the needs, preferences, interests, aspirations, and capabilities of the key market subjects, i.e., employers and HS, while bringing down the gap between the demand and supply as much as possible.

Formulation of the problem

Suppose $M_V = \{V, K, G, Q, U^p\}$ sets the model of demand for HS defining the competence requirements for those applying to a particular position. It represents the system of employers' preferences for candidates to a particular position expressed as a set of sought competencies of the right candidate and shapes the reference search profile of an HS. Here,

V is the set of vacancies expressed by candidate requirements for HS positions by employers;

$K = (L, C)$ is the set of basic competencies characterizing HS, comprising the set L of personal competencies required for working in HS and the set C of professional competencies reflecting the required functional abilities for filling a particular vacancy;

G is the system of the employer preferences with respect to levels of particular measures;

$Q: V \cdot K \cdot U^p \rightarrow G$ is the decision rule (evaluation model) for mapping of the set of preferences to the set of competencies;

U^p is the set of conditions offered to candidates applying for IT vacancies.

The supply model $M_S = \{S, K, W, Q^*, U^s\}$ reflects actual value of competencies and preferences of each individual HS, thus defining the search profile (professional profile) of HS. Here,

S is the set of HS looking for work and aspiring to a particular position;

$K = (L, C)$ is the set of personal and professional competencies of an individual HS, a potential candidate to a particular vacancy;

W - is the set of preferences of an HS;

$Q^*: S \cdot K \cdot U^s \rightarrow W$ is the mapping of the set of preferences of an HS to the set of competencies;

U^s is the workplace requirements of the HS.

The interaction between the set of reference demand conditions for HS and the set of actual conditions shaping their supply create the set of unique semi-structured (fuzzy) situations.

The purpose of managing supply and demand in the HS labor market is to identify (recognize) among the sets of actual search profiles of HS and reference search profiles the particular combination (pair) that shows the highest degree of agreement (convergence) of elements both from the point of preferences (reference requirements) of the employer and from the point of aspirations of the candidate.

With a mechanism available to evaluate supply and demand conditions and the degree of their conformity through the prism of the subjects' interest in the HS labor market, managerial decisions can be made as to the selection of the best candidate to a position (consequently, the selection of the best job).

In formal terms, the problem of identification of supply and demand conditions can be defined by three components $D = \langle V, S, R \rangle$, where:

V is the set of vacancies;

S is the set of HS;

R is the set of rules defining the relationship between the elements of sets V and S , i.e., rules helping to compare the descriptions of actual conditions of HS with all reference conditions of the demand side.

The recognition and evaluation of supply and demand conditions take the form of the mapping $F: D \rightarrow Z$, where Z is the solution of the problem D set with the intellectual system as a particular target condition meeting the purpose of recognition and evaluation in a particular situation.

Problem solution

Assume the demand in the HS labor market is defined by the set:

$V = \{V_1, V_2, \dots, V_k\}$ or $V = \{V_i, i = \overline{1, k}\}$ expressed in terms of the number of vacancies;

$L = \{l_1, l_2, \dots, l_n\}$ or $L = \{l_i, j = \overline{1, n}\}$ is the set of personal features required in a candidate to a particular position (job, workplace);

$C = \{c_1, c_2, \dots, c_m\}$ or $C = \{c_f, f = \overline{1, m}\}$ is an open set of competencies sought to fill an HS vacancy;

$U^p = \{u_1, u_2, \dots, u_p\}$ or $U^p = \{u_\gamma, \gamma = \overline{1, p}\}$ is a set of conditions offered to applicants to vacant HS jobs.

The demon model $v = (L, C)$ can be described by three matrices $V_L = \|l_{ij}\|_{kn}$, $V_C = \|c_{ir}\|_{km}$ and $V_U = \|u_{iz}\|_{kp}$, where every row (v_i) characterizes individual vacancies in the HS market; columns (l_n, c_m) represent the constantly expanding base of personality traits and competencies; elements l_{kn}, c_{km} express the level of individual characteristics required to fill the vacancy at the given time t ; and u_{qp} are the values of measures characterizing the conditions proposed to applicants for particular vacancies. Competency weights can also be taken into account; i.e. $\lambda = \{\lambda_1, \dots, \lambda_n\}$ is the set of weights of personal competencies, and $L = \{l_i, j = \overline{1, n}\}$; $\omega = \{\omega_1, \dots, \omega_m\}$ is the set of weights of professional competencies $C = \{c_f, f = \overline{1, m}\}$.

The degree of conformity between vacancy V_i and l_{ij} and c_{ir} is defined as fuzzy sets with membership functions

$$\mu_{l_{ij}}(V_i): V \times L \rightarrow [0,1], \quad \mu_{c_{ir}}(V_i): V \times C \rightarrow [0,1] \quad (1)$$

expressing the levels of individual competencies required to fill the vacancy as set by the employers.

Simultaneously, the conditions proposed to applicants are described by matrix $V_U = \|u_{iz}\|_{kp}$, where membership functions $\mu_{u_{iz}}(V_i): V \times U \rightarrow [0,1]$ represent fuzzy degrees of factors representing the conditions of employment.

Assume the supply in the HS labor market is given as set $S = \{S_1, S_2, \dots, S_q\}$ of HS looking for work and aspiring to a particular vacancy;

$L = \{l_i, j = \overline{1, n}\}$ is the set of actual competencies characterizing HS;

$C = \{c_f, f = \overline{1, m}\}$ is the set of actual competencies in each individual applicant to a vacancy;

$U = \{u_\gamma, \gamma = \overline{1, p}\}$ is the set of preferences of an HS expressed as his or her requirements for an HS vacancy.

The supply model $s = (l, c)$ is also given as three matrices $S_L = \|l_{ij}\|_{kn}$, $S_C = \|c_{ir}\|_{km}$, and $S_U = \|u_{iz}\|_{qp}$, where each row (s_q) characterizes individual candidates to proposed vacancies in the HS job market; columns (l_n, c_m) reflect the constantly expanding base of personal traits and

competencies; elements l_{qm}, c_{qm} are the levels of individual attributes required to fill a vacancy; and u_{qp} are the values of measures describing the HS requirements for a vacancy.

The degree of competency by an HS s_i is defined as follows:

$$\mu_{l_j}(S_i): S \times L \rightarrow [0,1], \mu_{c_r}(S_i): S \times C \rightarrow [0,1] \quad (2)$$

The HS requirements for a vacancy are expressed by the matrix $S_U = \|\mu_{iz}\|_{cp}$, and $\mu_{u_{cz}}(S_i): S \times U \rightarrow [0,1]$ reflects fuzzy measures of the IT specialist's requirements.

In fact, there are two sets of fuzzy situations describing the conditions of demand \tilde{v}_k and supply \tilde{s}_q in the HS labor market:

$$\tilde{s}_q = \{ \langle \mu_{l_j}(S_q) \rangle, \langle \mu_{c_r}(S_q) \rangle, \langle \mu_{u_{cz}}(S_q) \rangle \} = \{ \mu_{S_q}(y)/y \} \quad (3)$$

$$\tilde{v}_k = \{ \langle \mu_{l_j}(V_k) \rangle, \langle \mu_{c_r}(V_k) \rangle, \langle \mu_{u_{cz}}(V_k) \rangle \} = \{ \mu_{V_k}(y)/y \}. \quad (4)$$

Here, set $\tilde{s}_q = \{ \mu_{S_q}(y)/y \}$ accounts for fuzzy reference situations, and set $\tilde{v}_k = \{ \mu_{V_k}(y)/y \}$ accounts for fuzzy real situations.

For the purpose of managing supply and demand in the HS labor market, the problem of identification of the supply and demand conformity and subsequent hiring decision can reasonably be posed as a task of fuzzy profile recognition and evaluating the degree of fuzzy conformity of situations by measures and their levels. The search and decision making in these situations comes to comparisons of each fuzzy search profile of HS (applicants to one or several particular vacancies) with each reference search profile of employers and to identifying pairs with the highest degrees of convergence. In this setup, making a decision (logical conclusion) on the convergence (alignment) between supply and demand is based on situational management employing steps of evaluating the degree of convergence between two fuzzy situations. Approaches to convergence evaluation between any actual situation and each reference situation can involve single-stage or multistage procedures of identifying the degree of fuzzy inclusion of situation \tilde{s}_q in fuzzy situation \tilde{v}_k , degrees of fuzzy equality of \tilde{v}_k and \tilde{s}_q and fuzzy community of \tilde{v}_k and \tilde{s}_q , and other measures of convergence [20, 21].

Possible scenarios of supply and demand in the HS labor market

After the identification of the most acceptable employer (decision maker) – HS “pair” is completed on the basis of the degree of convergence among the sets of actual and reference search profiles, several possible scenarios are possible:

Scenario 1. One vacancy (employer request) – one applicant (HS).

In this case, if the degree of fuzzy convergence between two situations (reference search profile and candidate's search profile) is not lower than the employer's set threshold, then the decision is made to hire.

Scenario 2. The employer's preferences are met by several applicants (HS) at an acceptable degree of convergence of two fuzzy situations. They form a subset of fuzzy situations (alternatives), and the most suitable one should be selected.

In this case, the employer acting as an expert (decision maker) can be offered the following methods of decision making [21, 22]:

- (a) compare the degrees of convergence of reference and actual situations by the significance levels of the criteria characterizing the applicants to the vacancy and make a decision based on the convergence in the more significant criteria;
- (b) expand the list of evaluation criteria, further define input situations, and repeat the procedure of recognition;
- (c) reduce the problem to multi-criterion choice of the best solution (alternative) taking

into account the relative significance of criteria characterizing HS.

Scenario 3. Several employers who are interested in hiring of one HS are identified. A reverse problem occurs in this case: a subset of fuzzy reference situations (alternatives) is given in the form of proposed vacancies of different employers with fitting conditions, from which the HS has to choose in accordance with his preferences. In this scenario, the decision maker role lies with the IT HS who can:

- (a) compare the degrees of convergence between his aspirations and the criteria defining hiring conditions and make a decision based on the convergence of the most significant criteria;
- (b) expand the list of criteria for workplace evaluation, further define input situations, and repeat the recognition procedure;
- (c) reduce the problem to a multi-criterion choice of the best solution (alternative) taking into account the relative significance of criteria characterizing workplaces.

Conclusion

The proposed method is one of the possible options to help employers make reasonable hiring decisions to fill vacancies. The need for such assistance is dictated by a number of factors including the dynamic patterns of the business environment, the narrowing life cycles of implementing new ideas and technologies, and the need for systematic implementation of innovations to maintain competitive strength of the organization. In such circumstances, modern employers must constantly adapt their solutions to constantly changing managerial situations. Moreover, nowadays, the share of decisions to be made in uncertain and unconventional situations is rising significantly at all levels of management. While human resources are the main factor of competitive strength for organizations, the issues of support of decision making in managing staff and its intellectual potential have gained strategic importance.

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